THE INFLUENCE OF ORGANIC AMENDMENTS ON NUMBERS OF NEMATODES AND OTHER MICROORGANISMS IN THE SOIL

By

ARTHUR HARRIS TOMERLIN, JR.

A DISSERTATION PRESENTED TO THE GRADUATE COUNCIL OF
THE UNIVERSITY OF FLORIDA
IN PARTIAL FULFILLMENT OF THE REQUIREMENTS FOR THE
DEGREE OF DOCTOR OF PHILOSOPHY

UNIVERSITY OF FLORIDA

1969

ACKNOWLEDGMENTS

The author expresses his sincere appreciation to members of his supervisory committee: Dr. Grover C. Smart, Jr., Chairman, for his guidance, consultation, criticism, and, most of all, sincerity, in the course of his graduate studies; Dr. V. G. Perry for his timely help in preparing this manuscript; Dr. C. F. Eno and Dr. D. A. Roberts for reviewing and commenting on this dissertation.

Appreciation is extended to the U. S. D. A., Agricultural Research Service, whose funds under Contract No. 12-14-100-8142(34) made this research possible.

The author expresses his gratitutde and appreciation to his friend, Mr. R. W. Patrick, for his technical assistance on several occasions.

And last, the author sincerely thanks his wife, Mireya, for her patience, encouragement, and understanding during the course of his graduate studies.

CONTENTS

LIST OF TABLES

Appendix table

LIST OF FIGURES

INTRODUCTION AND LITERATURE REVIEW

Changes occur in the chemical, physical, and biological properties of soils into which organic materials have been incorporated (1). One biological change is that certain populations of plant pathogens tend to increase in numbers. The fungus that causes black root rot of tobacco increased greatly on resistant plants when the plants were first treated with aqueous extracts of decomposing green material from rye and timothy (27). This conditioning of the tobacco plants was attributed to toxic substances liberated or synthesized or both during the decomposition of organic material (26, 29).

Another biological change that occurs when organic materials are incorporated into the soil is that populations of certain other plant pathogens tend to decrease in numbers (25, 37). Linford et al. (19) reported reduction of a population of a root-knot nematode, Meloidogyne sp., during decomposition of chopped pineapple, sugarcane, and a coarse grass. They attributed this reduction to the build-up of predacious fungi. The occurrences, mechanisms, and roles in control of nematodes by predacious or parasitic fungi have been investigated and discussed by numerous authors (5,6,7,8,9,13,20,21,22,32).

Some workers reported a build-up of predacious nematodes in amended soils and suggested that these organisms were important in the control of plant parasitic nematodes (19,23). Predacious nematodes occur in the families Mononchidae, Tripylidae, Diplogas-

teridae and Aphelenchidae, and the superfamiles Dorylaimoidea and Mermithoidea (13). The rearing and inoculating of predacious nematodes into soil infested with plant parasitic nematodes was proposed and initial experiments using Mononchus papillatus Bastian carried out by Cobb (4) and Steiner and Heinly (34). Only under laboratory conditions did they demonstrate the effectiveness of M. papillatus in controlling root-knot nematodes.

Other workers believe that organic materials added to the soil may be toxic to plant parasitic nematodes. Ellenby (10,11) found that extracts of certain members of the plant family Cruciferae and mustard oil (allyl isothiocyanate) were toxic to Heterodera rostochiensis Wollenweber. Renninger et al. (30) reported that hydrogenated fish oil, when sprayed over infested soil, reduced numbers of Radopholus similis (Cobb) Thorne. They hypothesized that control was due to an interference of the respiration and oxidation processes in the nematodes, thus suffocating them. Other organic materials that have been reported to reduce populations of plant parasitic nematodes include alfalfa hay, oat straw, lespedeza hay, flax (16), castor pomace (18), sawdust (33), raspberry canes and roots (36), and soybean meal and oil (38).

Biodegradation of organic materials and/or biosynthesis of degraded products result in nematicidal compounds that are active in soils (17,28,31). Sayre et al. (31) obtained and identified a nematicidal compound, butyric acid, from decomposing rye and timothy plant residues. They also suggested that other low molecular weight carboxylic acids, such as formic, acetic, and propionic,

might also be produced during decomposition and be nematicidal. Taylor and Murant (36) found that the polyphenols hydroquinone, catechol, and resorcinol are nematicidal. They suggested that these polyphenols might come from the tannin fraction of decomposing plant materials.

Another theory is that the organic materials in the soil may so alter the chemical equilibrium in the soil that numbers of plant parasitic nematodes are reduced. Johnson (15) reported that, in amended soils, numbers of a root-knot nematode species were reduced at temperatures from 5° to 30° C in soils of low and medium moisture levels and at pH between 4.6 and 5.5. Mankau (24) suggested that control of nematodes in amended soils was due to factors such as alteration in available soil oxygen and nitrogen, and in the pH. Stolzy _et al_. (35) found that nematodes could survive at a level of 2% oxygen. Eno _et al_. (12) observed nematode reduction in soils containing 136 ppm of ammoniacal nitrogen; the largest reduction occurred in soil containing 365 ppm of ammoniacal nitrogen. Wallace (39) reported an optimum level of 10% carbon dioxide for nematodes.

The reduction of numbers of plant parasitic nematodes by the addition of organic amendments to the soil is well documented in the literature. The purpose of this research was to investigate quantitatively some of the factors that might be responsible for this reduction. Factors studied were populations of nematodes, relative numbers of fungi and bacteria, levels of nitrogen and carbon dioxide, ammonium acetate extractable Ca, K, Mg, and P, and nematicidal chemicals produced by the biodegradation of the organic amendments.

MATERIALS AND METHODS

Predacious nematode experiment. - Thirty clay pots of a 10-cm size were filled with Arredondo fine sand and autoclaved for forty minutes at 18 psi. After three days, the pots were planted to sweet corn, *Zea mays* L., 'Silver Queen'. Ten pots were inoculated with fifty hand-picked specimens of the sting nematode, *Belonolaimus longicaudatus* Rau; ten pots were inoculated with fifty hand-picked specimens of *B. longicaudatus* plus fifty hand-picked specimens of *Mononchoides* sp. (undescribed); and ten pots were not inoculated with nematodes. All pots were kept in a growth room held at a temperature of 22° C with a photoperiod of twelve hours. Each pot of soil was watered as needed. Plant heights (cm) and green weights (g) of shoots and roots were recorded after eight weeks. Dry weights of shoots and roots were determined after drying at 60° C for forty-eight hours. The soil in each pot was mixed thoroughly and a 100-ml sample was processed by the sugar flotation-centrifugation method (3) and numbers of *B. longicaudatus* and *Mononchoides* sp. determined for each pot of soil.

Soil amendment experiments. - An Arredondo fine sand was selected which was infested with the plant parasitic nematodes *B. longicaudatus*, *Hoplolaimus galeatus* (Cobb) Thorne, and *Criconemoides ornatus* Raski. Rhabditid, diplogasterid, cephalobid, and dorylaimid types of nematodes were also present. Amendments added

were alfalfa meal, cottonseed meal, or rice straw at rates equivalent to 0, 9, and 18 M.T./ha (0, 4, and 8 short tons per acre). For each replicate the appropriate amount of the amendment (0, 80, or 160 g), 10 g of $CaCO_3$, 3 g of fertilizer (10-10-10), and 20 kg of soil were placed in a concrete mixer and the mixer operated for two minutes. The mixture then was placed in redwood flats (43 x 25 x 17 cm). Each treatment was replicated six times, but only five were sampled; the sixth flat was used to replace soil removed from the test flats when sampling. Ten seeds of common bean, *Phaseolus vulgaris* L., 'Contender' were planted in each flat. The seeds in the flats amended with cottonseed meal germinated poorly or not at all, and these flats were replanted seven weeks after the initiation of the experiment. Three completely randomized experiments were conducted; alfalfa meal was used in each of the three experiments and cottonseed meal and rice straw were used in only one of the experiments.

The following data were recorded weekly: numbers of plant parasitic and other nematodes; relative numbers of fungi and bacteria obtained by plate counts made on rose-bengal and soil-extract agar, respectively (2); soil pH; nitrates by the phenoldisulfonic acid method; and ammonium acetate extractable Ca, K, Mg, and P (14). In addition bean seed germination, plant heights, and green weights of bean pods were recorded. Laboratory experiments were conducted with the amended soils to obtain data on carbon dioxide-carbon evolution by using NaOH in a closed system as the absorber of evolved carbon dioxide. Data were statistically analyzed using an analysis of

variance with 'F' test.

Extraction experiment. - Nine two-quart plastic freezer bags were filled with 300 g of Arrendondo fine sand. Alfalfa or cottonseed meal at rates equivalent to 18 M.T./ha (2.4 g) were added to each of three bags and mixed thoroughly. Nothing was added to the other three bags. All nine bags were placed in an incubator at 25° C and water added to each when needed to keep the soil moist. Also, the soil was stirred to keep it aerated. After seven, fourteen, and twenty-one days, three bags, one each containing alfalfa meal and cottonseed meal and one control, were removed from the incubator and each placed in a 1,000-ml beaker with 300 ml of a weak aqueous solution of NaOH at pH 11 and mixed for 1.5 hours with a cone-driven stirrer. The solution was readjusted to pH 11 with 0.5 N NaOH and mixed another 1.5 hours. The supernatant was centrifuged for fifteen minutes at 2,500 rpm, then filtered through Whatman's #1 filter paper in a Buchner funnel. The solution then was acidified slowly to a pH 4.5 with 0.5 N HCl, placed in a separatory funnel and 200 ml of anhydrous ether added. The solution was shaken vigorously and allowed to separate, with both fractions being collected. The water fraction was again washed with 200 ml of ether. The two ether fractions were combined and the ether was evaporated under a partial vacuum. The residue was taken-up in 5 ml of water and this was used in the bioassays.

The bioassays were conducted with active specimens of *B. longicaudatus*. Ten specimens were placed in a BPI watch glass containing

1 ml of the extracts from either the alfalfa meal, cottonseed meal, unamended control, or distilled water. Each of the four treatments was replicated three times. Motility data were taken at the beginning and end of each test which varied from twenty-four to thirty hours in duration. Motility was determined by applying tactile stimulation with a dental pulp canal file while observing the specimen with a dissecting microscope.

RESULTS

Predacious nematode experiment. - An average of 140 specimens of *Belonolaimus longicaudatus* per pot were recovered from those pots inoculated with fifty specimens of this species only. An average of 207 specimens of *B. longicaudatus* and seventy-four specimens of *Mononchoides* sp. were recovered from pots inoculated with fifty specimens of each organism (Table 1). However, populations of each nematode varied greatly between individual pots in both treatments.

Average dry weights of the shoots of corn plants were highest in the control and lowest where *B. longicaudatus* was used alone (Table 1). Average dry weights of the roots were highest where both nematodes were used together and lowest where *B. longicaudatus* was used alone. Much variation was noted between dry weights of corn plants in individual treatments.

Soil amendment experiments. - Population levels of *B. longicaudatus* were reduced by the 9 and 18 M.T./ha rates of the amendments for at least seven weeks. In the alfalfa meal-amended soils, populations of *B. longicaudatus* in the controls were noted to increase during the fourth week and to reach maximum numbers during the seventh week (Table 2). Populations in the 9 M.T./ha treatment started to increase during the seventh week and obtained a maximum number by the eleventh week. Populations in the 18 M. T./ha treatment started to increase in the eleventh week. Bean plants were producing fruit by the seventh week and continued to do so through the twelfth week when the experiment was stopped.

Table 1. Average plant heights and weights and recovery of *Belonolaimus longicaudatus* and *Mononchoides* sp. nematodes eight weeks after inoculation into soil planted to corn *Zea mays* 'Silver Queen'.

Inoculum	Height of plants	Dry wt. of plants		Numbers of nematodes	
		Shoots	Roots	*B. longicaudatus*	*Mononchoides* sp.
	cm	g	g	Numbers/pot	
Uninoculated	44	1.66	0.81	1	0
50 *B. longicaudatus*	36	1.15	0.73	140	2
50 *B. longicaudatus* + 50 *Mononchoides* sp.	38	1.44	0.94	207	74

Table 2. Numbers of Belonolaimus longicaudatus as influenced by organic amendments in Arredondo fine sand.

Treatment & rates	Weeks																
	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
	Numbers per 160 g of soil																
Alfalfa meal																	
None	3	1	2	3	11^{a*}	23^{a}	56^{a}	61^{a}	52^{a}	37^{a}	30^{a}	55^{a}	45				
9 M.T./ha	3	4	1	0	1^{b}	4^{b}	3^{b}	15^{b}	23^{b}	16^{b}	45^{b}	46a	35				
18 M.T./ha	3	2	0	0	2^{b}	2^{b}	2^{b}	2^{c}	5^{c}	6^{c}	5^{c}	13^{b}	33				
Cottonseed meal																	
None	0	1	5	0	0	2	23^{a*}	22^{a}	13^{a}	29^{a}	24^{a}	55^{a}	40^{a}	-	-	-	-
9 M.T./ha	0	1	0	0	1	0	0^{b}	0^{b}	1^{b}	0^{b}	0^{b}	0^{b}	1^{b}	0	0	1	0
18 M.T./ha	0	0	0	0	0	0	0^{b}	0^{b}	0^{b}	0^{b}	0^{b}	0^{b}	0^{b}	0	1	1	0
Rice straw																	
None	0	1	5	0	0	2	23^{a*}	22^{a}	13	29^{a}	24^{a}	55^{a}	40^{a}				
9 M.T./ha	0	0	1	0	1	8	10^{b}	7^{b}	7	13^{b}	10^{b}	9^{b}	15^{b}				
18 M.T./ha	0	1	0	1	1	1	7^{b}	7^{b}	7	11^{b}	7^{b}	7^{b}	42^{a}				

*Different letters in a column,within each group of 3 values, differ significantly at the 5% level of probability.

In the cottonseed meal-amended soil, populations of the sting nematode were almost undetectable throughout the experiment at both the 9 and 18 M.T./ha rates (Table 2). Populations in the control were significantly higher than in the treatments from the sixth week through the twelfth week. As stated above, the seeds planted at the initiation of the test failed to germinate and the flats were reseeded after seven weeks. These seeds germinated considerably better (Table 12) and plant growth was good (Tables 13 and 14), yet suppression of the sting nematode populations was evident through the sixteenth week.

In the rice straw-amended soils, sting nematode populations began to increase in the twelfth week (Table 2). The number of nematodes in the control was significantly higher than the numbers in the 9 and 18 M.T./ha treatments from the sixth through the eleventh weeks. By the twelfth week the population of nematodes had increased greatly in the 18 M.T./ha rate while the population in the 9 M.T./ha rate remained at a low level. There were mature plants in all flats by the seventh week of the experiment.

Populations of Hoplolaimus galeatus declined in all treatments (Table 3). In the alfalfa meal treatments, numbers were significantly less than in the controls in the second and third weeks. In the cottonseed meal treatments, numbers were significantly less than in the controls from the third through the twelfth week. In the rice straw treatments, numbers were significantly less than in the controls only from the second through the fourth week.

Populations of Criconemoides ornatum declined in all treatments

Table 3. Numbers of <u>Hoplolaimus galeatus</u> as influenced by organic amendments in Arredondo fine sand.

Treatment & rates	Weeks 0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
	Numbers per 160 g of soil																
Alfalfa meal																	
None	62	26	27^{a*}	21^{a}	20	17	15	7	13	11	14	12	13				
9 M.T./ha	62	26	15^{b}	12^{b}	14	11	11	11	14	12	16	12	15				
18 M.T./ha	62	25	11^{b}	14^{b}	19	18	12	12	9	8	13	7	9				
Cottonseed meal																	
None	46	28^{a*}	34^{a}	29^{a}	20^{a}	18^{a}	20^{a}	14^{a}	13^{a}	20^{a}	17^{a}	21^{a}	18^{a}	-	-	-	-
9 M.T./ha	46	30^{a}	19^{b}	13^{b}	6^{b}	6^{b}	7^{b}	2^{b}	4^{b}	1^{b}	5^{b}	1^{b}	4^{b}	1	13	1	5
18 M.T./ha	46	51^{b}	11^{b}	13^{b}	6^{b}	4^{b}	1^{b}	1^{b}	4^{b}	1^{b}	0^{b}	4^{b}	3^{b}	0	0	2	1
Rice straw																	
None	46	28	34^{a*}	29^{a}	20^{a}	18	20	14	13	20^{a}	17	21	18				
9 M.T./ha	46	32	17^{b}	15^{b}	11^{b}	25	15	14	11	31^{b}	17	20	13				
18 M.T./ha	46	18	12^{b}	11^{b}	22^{a}	18	20	16	18	30^{b}	22	15	15				

*Different letters in a column, within each group of 3 values, differ significantly at the 5% level of probability.

(Table 4). Numbers in the controls initially declined at a slower rate than in the amended soils but no continuous significant differences occurred.

Number of rhabditid nematodes in soil amended with alfalfa meal increased significantly over the controls after the first week (Table 5). In the 9 M.T./ha rate, numbers reached a peak in the third week and declined sharply in the fourth week. In the 18 M.T./ha rate, numbers reached a peak in the second week and declined sharply in the fifth week but remained significantly higher than the control through the seventh week. Rhabiditids in the cotton seed meal treatment reached maximum population levels in the second week. In the 9 M.T./ha rate, numbers declined by the sixth week to levels insignificant from the control. The 18 M.T./ha rate remained significantly different from the control through the eleventh week. Rhabditids in the rice straw treatments reached maximum population levels in the third and fourth weeks. However, these maximum levels were far below those of the other treatments. In both the 9 and 18 M.T./ha rate treatments, numbers declined sharply the week after maximum numbers were reached.

The diplogasterid nematodes in the alfalfa meal-amended soils increased significantly to maximum population levels in the second week, then decreased rapidly thereafter (Table 6). Populations in the cottonseed meal-amended soil increased significantly in the first week and by the second week decreased to almost undetectable levels. Populations of diplogasterids in the soils amended with rice straw were almost undetectable after the pretreatment counts.

Table 4. Numbers of <u>Criconemoides</u> <u>ornatum</u> as influenced by organic amendments in Arredondo fine sand.

Treatment & rates	Weeks																
	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
	Numbers per 160 g of soil																
Alfalfa meal																	
None	330	165	158^{a*}	118	102	61	62	40	50	26	68	49	44				
9 M.T./ha	330	133	116^{ab}	79	91	63	38	33	48	85	48	48	51				
18 M.T./ha	330	119	81^{b}	80	82	90	51	60	33	28	42	24	80				
Cottonseed meal																	
None	312	219^{a*}	137^{a}	137	102	103^{a}	78^{a}	49	39	44	88	88^{a}	58	-	-	-	-
9 M.T./ha	312	134^{b}	109^{a}	125	94	154^{b}	125^{b}	76	81	50	92	40^{b}	46	64	81	66	35
18 M.T./ha	312	159^{b}	63^{b}	116	96	72^{a}	75^{a}	48	62	43	56	37^{b}	64	26	32	31	24
Rice straw																	
None	312	219^{a*}	137^{a}	137^{a}	102	103	78	49	39	44	88	88	58				
9 M.T./ha	312	124^{b}	67^{b}	57^{b}	93	78	72	74	62	50	65	53	65				
18 M.T./ha	312	101^{b}	68^{b}	130^{a}	95	88	68	74	70	61	65	55	54				

*Different letters in a column, within each group of 3 values, differ significantly at the 5% level of probability.

Table 5. Numbers of rhabditids as influenced by organic amendments in Arredondo fine sand.

Treatment & rates	Weeks																
	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
	Numbers per 160 g of soil																
Alfalfa meal																	
None	34	10	46^{a*}	243^{a}	153^{a}	78^{a}	63^{a}	57^{a}	40	67	69	57	67^{a}				
9 M.T./ha	34	29	527^{b}	634^{b}	209^{a}	97^{ab}	105^{ab}	138^{b}	83	86	85	82	125^{ab}				
18 M.T./ha	34	34	778^{b}	624^{b}	594^{b}	178^{b}	187^{b}	157^{b}	70	43	69	79	246^{b}				
Cottonseed meal																	
None	9	6^{a*}	28^{a}	534^{a}	133^{a}	126^{a}	56^{a}	22^{a}	44^{a}	86^{a}	67^{a}	63^{a}	76	-	-	-	-
9 M.T./ha	9	83^{b}	$1,712^{b}$	809^{b}	$1,218^{b}$	363^{b}	137^{a}	47^{a}	50^{a}	51^{a}	82^{a}	31^{a}	95	45	55	32	19
18 M.T./ha	9	36^{ab}	$2,289^{c}$	952^{b}	699^{c}	795^{c}	352^{b}	160^{b}	481^{b}	269^{b}	286^{b}	195^{b}	133	77	53	39	40
Rice straw																	
None	9	6	28^{a*}	534^{a}	133^{a}	126^{ab}	56	22	44	86^{ab}	67	63	76				
9 M.T./ha	9	6	89^{b}	104^{b}	350^{b}	78^{a}	90	94	91	164^{a}	129	78	91				
18 M.T./ha	9	4	222^{c}	641^{a}	146^{a}	174^{b}	100	87	93	46^{b}	95	72	68				

*Different letters in a column, within each group of 3 values, differ significantly at the 5% level of probability.

Table 6. Numbers of diplogasterids as influenced by organic amendments in Arredondo fine sand.

Treatment & rates	Weeks 0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
	Numbers per 160 g of soil																
Alfalfa meal																	
None	11	3	16^{a*}	21^{ab}	5^{a}	21	4^{a}	9^{a}	1	4	1	0	1				
9 M.T./ha	11	5	65^{b}	19^{a}	6^{a}	26	21^{b}	14^{a}	5	5	1	4	2				
18 M.T./ha	11	1	102^{c}	39^{b}	24^{b}	21	14^{b}	27^{b}	7	4	4	2	2				
Cottonseed meal																	
None	11	0^{a*}	0	0	0	0	0	0	0	0	0	0	0	-	-	-	-
9 M.T./ha	11	14^{b}	0	0	0	0	0	0	1	1	0	0	0	0	0	0	0
18 M.T./ha	11	26^{b}	0	1	0	0	0	3	0	3	0	0	0	0	0	0	0
Rice straw																	
None	11	0	0	0	0	0	0	0	0	0	0	0	0				
9 M.T./ha	11	0	0	0	0	0	0	2	0	0	0	0	0				
18 M.T./ha	11	0	0	0	0	0	1	1	0	0	0	0	0				

*Different letters in a column, within each group of 3 values, differ significantly at the 5% level of probability.

The numbers of cephalobid nematodes in the alfalfa meal amended soils were not significantly different from the control until the seventh week at which time they were lower in number (Table 7). By the eighth week, numbers in the amended soils were higher than in the control and this trend held generally during the remainder of the experiment, although the differences were not always significant. Populations in the cottonseed meal-amended soil remained very low through the first fourteen weeks, then increased sharply in the fifteenth week. Populations of cephalobids in the rice straw-amended soils were low through the first ten weeks, with a significant increase occurring in the eleventh week in the 9 M.T./ha rate.

The dorylaimid nematodes in the alfalfa meal-amended soils decreased and remained at very low numbers throughout the experiment. Those in the control increased in the sixth week and, with the exception of the eighth week, remained significantly higher than in the treatments through the twelfth week (Table 8). Populations in the cottonseed meal-amended soils behaved very similar to those in alfalfa amended soils. Dorylaimids in the rice straw-amended soils decreased in the first week and remained at low insignificant levels throughout the remainder of the experiment except for the ninth and eleventh weeks.

Very low and erratically occurring populations of aphelenchoid nematodes were present (Appendix Table 5).

The relative numbers of fungi were significantly higher in the alfalfa meal-amended soils than in the control throughout the experi-

Table 7. Numbers of cephalobids as influenced by organic amendments in Arredondo fine sand.

Treatment & rates	Weeks																
	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
	Numbers per 160 g of soil																
Alfalfa meal																	
None	9	8	5	2	2	8	16	36a*	27	51	42a	66a	86				
9 M.T./ha	9	13	7	3	0	6	10	14b	36	49	49a	97ab	93				
18 M.T./ha	9	14	11	1	1	11	16	12b	51	53	99b	109b	121				
Cottonseed meal																	
None	9	0	0	0	0	0	0	0	1	1	5	11	6	-	-	-	-
9 M.T./ha	9	3	0	1	1	0	0	0	0	0	4	13	1	4	24	70	79a*
18 M.T./ha	9	6	0	1	1	0	0	0	0	0	0	6	4	4	8	106	26b
Rice straw																	
None	9	0	0	0	0	0	0	0	1	1	5	11a*	6a				
9 M.T./ha	9	1	3	2	0	0	1	0	1	1	4	55b	25b				
18 M.T./ha	9	0	1	1	0	0	3	0	0	3	1	8a	11ab				

*Different letters in a column, within each group of 3 values, differ significantly at the 5% level of probability.

Table 8. Numbers of dorylaimids as influenced by organic amendments in Arredondo fine sand.

Treatment & rates	Weeks 0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
	Numbers per 160 g of soil																
Alfalfa meal																	
None	12	9	8	9	4	5	12a*	23a	7	15a	15a	30a	17a				
9 M.T./ha	12	5	14	3	0	3	1b	0b	2	1b	2b	7b	2b				
18 M.T./ha	12	7	7	1	5	5	1b	2b	1	0b	5b	3b	2b				
Cottonseed meal																	
None	12	8	3	2	1	0	8a*	9a	2	17a	10a	29a	10a	-	-	-	-
9 M.T./ha	12	4	0	1	1	0	0b	0b	0	1b	1b	4b	1b	11	6	4	3
18 M.T./ha	12	6	0	1	1	4	0b	1b	1	2b	0b	1b	1b	5	2	1	1
Rice straw																	
None	12	8	3	2	1	0	8	9	2	17a*	10	29a	10				
9 M.T./ha	12	4	1	1	4	6	4	5	1	0b	1	27a	8				
18 M.T./ha	12	8	3	0	1	4	4	1	2	2b	6	3b	10				

*Different letters in a column, within each group of 3 values, differ significantly at the 5% level of probability.

ment, except for the tenth week (Table 9). Relative numbers in the cottonseed meal-amended soils were significantly different than in the control the first week and from the fourth week to the eleventh week. In the 9 M.T./ha rate, relative numbers were higher than in the control, but in the 18 M.T./ha rate relative numbers were lower in several cases than in the control (Table 9). Relative numbers of fungi in the 9 and 18 M.T./ha rates of rice straw were significantly higher than the control from the third week through the eighth week. Relative numbers in the 18 M.T./ha rate were also significantly higher in the tenth and eleventh weeks but not in the ninth week.

The relative numbers of bacteria were significantly higher in alfalfa meal-amended soils at the 18 M.T./ha rate than in the controls throughout the experiments except in the ninth week (Table 10). In the 9 M.T./ha rate, relative numbers usually were not significantly different from the controls. The relative numbers in the cottonseed meal-amended soils were significantly higher than in the controls throughout the experiments except in the second, third, and eleventh weeks at the 9 M.T./ha rate, and the third week at the 18 M.T./ha rate. The relative numbers of bacteria in soil amended with rice straw were significantly higher than in the control from the third to the fifth week at the 18 M.T./ha rate and in the fifth week at the 9 M.T./ha rate.

Total carbon dioxide evolution in soil amended with alfalfa meal was significantly different from the controls (Fig. 1). The highest production was in the 18 M.T./ha rate with a total production of 235 mg per 100 g of soil in 37 days as compared to 17 mg in the

Table 9. Relative numbers of fungi as influenced by organic amendments in Arredondo fine sand.

Treatment & rates	Weeks 0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
	Relative numbers per 1 g of soil in thousands																
Alfalfa meal																	
None	9	4^{a*}	5^a	7^a	6^a	4^a	4^a	4^a	7^a	13^a	6	6^a	4^a				
9 M.T./ha	9	21^b	33^b	34^b	51^b	48^b	56^b	30^b	42^b	22^b	14	21^b	23^b				
18 M.T./ha	9	50^c	58^c	59^c	66^b	55^b	55^b	66^c	42^b	41^c	8	31^b	28^b				
Cottonseed meal																	
None	9	1^{a*}	1	4	2^a	3^a	2^a	1^a	2^a	7^a	5^a	9^a	5	-	-	-	-
9 M.T./ha	9	10^b	1	0	15^b	49^b	18^b	24^b	17^b	21^b	16^b	18^b	4	24	7	16	21
18 M.T./ha	9	15^b	1	0	10^b	22^c	19^b	5^a	5^a	39^c	2^a	1^c	1	18	14	5	12
Rice straw																	
None	9	1^{a*}	1	4^a	2^a	3^a	2^a	1^a	2^a	7	5^a	9^a	5				
9 M.T./ha	9	7^b	1	17^b	15^b	30^b	11^b	10^b	15^b	7	7^a	4^a	12				
18 M.T./ha	9	2^a	4	14^b	24^c	27^b	25^c	7^b	23^c	13	18^b	79^b	8				

*Different letters in a column, within each group of 3 values, differ significantly at the 5% level of probability.

Table 10. Relative numbers of bacteria as influenced by organic amendments in Arredondo fine sand.

Treatment & rates	Weeks 0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
	Relative numbers per 1 g of soil in millions																
Alfalfa meal																	
None	2	4^{a*}	2^{a}	2^{a}	2^{a}	2^{a}	1^{a}	3^{a}	3^{a}	5	2^{a}	2^{a}	1^{a}				
9 M.T./ha	2	7^{a}	7^{a}	58^{b}	7^{ab}	25^{b}	40^{b}	11^{b}	8^{a}	8	13^{b}	12^{ab}	6^{a}				
18 M.T./ha	2	14^{b}	21^{b}	14^{c}	9^{b}	15^{c}	12^{c}	22^{c}	23^{b}	10	13^{b}	22^{b}	19^{b}				
Cottonseed meal																	
None	4	1^{a*}	4^{a}	1	2^{a}	2^{a}	1^{a}	1^{a}	1^{a}	1^{a}	2^{a}	1^{a}	1^{a}	-	-	-	-
9 M.T./ha	4	16^{b}	2^{a}	4	9^{b}	22^{b}	12^{b}	19^{b}	12^{b}	14^{b}	15^{b}	6^{a}	17^{b}	15	14	14	15
18 M.T./ha	4	38^{c}	13^{b}	6	9^{b}	18^{b}	12^{b}	15^{b}	17^{b}	30^{c}	14^{b}	29^{b}	15^{b}	13	15	11	8
Rice straw																	
None	4	1	4	1^{a*}	2^{a}	2^{a}	1	1	1	1	2	1	1				
9 M.T./ha	4	6	9	6^{ab}	4^{a}	12^{b}	3	1	3	5	4	2	5				
18 M.T./ha	4	5	3	12^{b}	12^{b}	15^{b}	6	4	3	5	4	7	1				

*Different letters in a column, within each group of 3 values, differ significantly at the 5% level of probability.

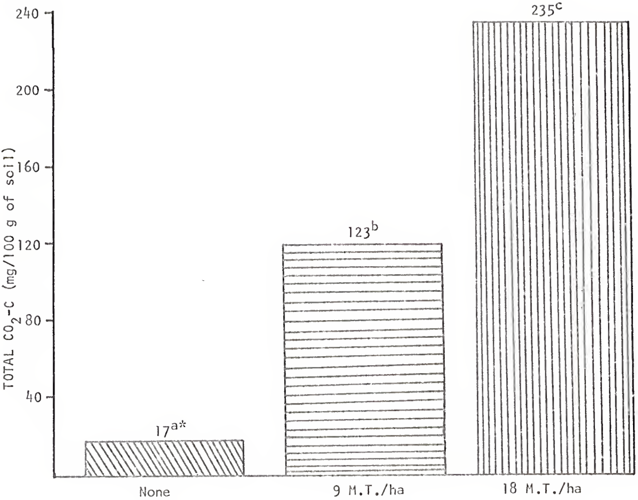

Figure 1. Total CO_2-C production in Arredondo fine sand amended with different rates of alfalfa meal.

*Different letters means significance at the 5% level of probability.

control. Production was intermediate at the 9 M.T./ha rate.

Nitrate accumulation in the 18 M.T./ha rate of alfalfa meal remained significantly higher than the control from the third through the twelfth week and in the 9 M.T./ha rate from the third through the fifth week (Table 11). The highest nitrate accumulation was recorded in the 18 M.T./ha rate of alfalfa meal with a high of 43 ppm in the fifth week as compared with a high of 6 ppm in the fourth week in the control. Accumulation was intermediate in the 9 M.T./ha rate at 29 ppm in the fourth week. Nitrate accumulation in soil amended with cottonseed meal at 18 M.T./ha was significantly higher than in the controls from the fifth through the twelfth week with the exception of the tenth week. In the 9 M.T./ha rate, accumulation was significantly higher than in the control in the third week and from the fifth through the twelfth weeks. Levels of nitrates were very low in the rice straw-amended soils. Such a wide C:N ratio existed that the nitrogen was immobilized by the third week, thereby causing plants to suffer a nitrogen deficiency. Nitrogen deficiency did not occur in the plants grown in soils amended with alfalfa meal and cottonseed meal.

No consistent differences in pH and amounts of ammonium acetate extractable Ca, K, Mg, and P were observed between treatments in the experiments (Appendix Tables 6,7,8,9, and 10).

Germination of seed of Phaseolus vulgaris was inhibited in soils amended with alfalfa meal and cottonseed meal (Table 12). By the fifth week, all plants in the cottonseed meal-amended soil were dead. The

Table 11. Nitrates in Arredondo fine sand amended with organic materials.

Treatment & rates	Weeks 1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
	ppm															
Alfalfa meal																
None	3	3	2^{a*}	6^{a}	1^{a}	1^{a}	0^{a}	0^{a}	0^{a}	1^{a}	0^{a}	1^{a}				
9 M.T./ha	2	6	23^{b}	29^{b}	10^{b}	3^{a}	3^{a}	3^{a}	1^{a}	1^{a}	1^{a}	1^{a}				
18 M.T./ha	4	5	12^{c}	20^{b}	43^{c}	37^{b}	38^{b}	32^{b}	35^{b}	17^{b}	21^{b}	20^{b}				
Cottonseed meal																
None	3	3	2^{a*}	6^{ab}	1^{a}	1^{a}	0^{a}	0^{a}	0^{a}	1^{a}	0^{a}	1^{a}	-	-	-	-
9 M.T./ha	2	5	10^{b}	13^{a}	26^{b}	19^{b}	33^{b}	24^{b}	21^{b}	9^{b}	8^{b}	13^{b}	17^{a}	20^{a}	13^{a}	13^{a}
18 M.T./ha	2	1	2^{a}	1^{b}	12^{c}	13^{b}	27^{b}	20^{b}	21^{b}	6^{ab}	23^{c}	25^{c}	32^{b}	34^{b}	31^{b}	31^{b}
Rice straw																
None	3	3^{ab*}	2	6	1	1	0	0	0	1	0	1				
9 M.T./ha	2	1^{a}	1	0	1	0	0	0	0	1	0	1				
18 M.T./ha	2	8^{b}	1	1	0	0	0	0	0	1	0	1				

*Different letters in a column, within a group of 3 values, differ significantly at the 5% level of probability.

Table 12. Average per cent of germination of *Phaseolus vulgaris* in amended soils.

Treatments	Germination	
	9 M.T./ha	18 M.T./ha
	%	%
Alfalfa meal	84	84
Rice straw	100	92
Cottonseed meal (1st. planting)	50	4
*Cottonseed meal (2nd. planting)	90	60
Control	96	

*Replanted in the 7th week of the experiment after all plants in the soil amended with cottonseed meal at 18 M.T./ha died.

soil was replanted in the seventh week; more seeds germinated and the plants survived.

The greatest average maximum height of bean plants was 43.5 cm and occurred in the 9 M.T./ha rate of cottonseed meal three weeks after replanting (Table 13). The least average maximum height was 21.9 cm and occurred in the 18 M.T./ha rate of cottonseed meal. Inhibition of plant growth was still present in the 18 M.T./ha rate of cottonseed meal eleven weeks after initiation of the experiment.

The total green weights of bean pods produced by the plants in the 9 M.T./ha rate of alfalfa meal was the highest at 511.6 g (Table 14). The lowest weights occurred in the rice straw with 50.2 g and 31.9 g for the 9 and 18 M.T./ha rates, respectively, with weights produced in cottonseed meal-amended soils intermediate.

Extraction experiment - At the end of seven days of incubation, extracts from both the alfalfa meal and cottonseed meal reduced motility of specimens of *B. longicaudatus* to 63% and 50%, respectively. At the end of fourteen days of incubation, specimens were reduced to 23% motility in the alfalfa meal and 20% in the cottonseed meal and at the end of twenty-one days of incubation to 67% for alfalfa meal and 40% for cottonseed meal (Table 15).

Table 13. Average maximum plant heights of *Phaseolus vulgaris* in the greenhouse experiments.

Treatments	Plant heights	
	9 M.T./ha	18 M.T./ha
	cm	cm
Alfalfa meal	37.5	33.8
Rice straw	31.8	30.1
*Cottonseed meal	43.5	21.9
Control	42.5	

*The heights recorded in the alfalfa meal, rice straw, and control treatments were taken eleven weeks after planting. The heights recorded in the cottonseed meal treatment were taken three weeks after planting.

Table 14. Total green weight of bean pods produced on plants of *Phaseolus vulgaris* in amended soils.

Treatments	Green weight 9 M.T./ha g	18 M.T./ha g
Alfalfa meal	511.6	294.3
Rice straw	50.2	31.9
*Cottonseed meal	306.9	126.4
Control	329.1	

*Growth period of plants in the cottonseed meal treatments were two weeks shorter than the other treatments.

Table 15. Motility of *Belonolainmus longicaudatus* as influenced by extracts from organic amended Arredondo fine sand.

	7 days	14 days	21 days
	Per Cent Motility of Specimens		
Alfalfa meal 18 M.T./ha	63	23	67
Cottonseed meal 18 M.T./ha	50	20	40
None	80	87	100
Distilled water	100	97	100

SUMMARY AND CONCLUSIONS

Predacious nematode experiment. - The results of this experiment indicate that the species of Mononchoides used provides little, if any, biological control of B. longicaudatus. No explanation can be given as to why roots and shoots of corn plants weighed more, and why more B. longicaudatus and Mononchoides sp. occurred when they were used together than where equal numbers of B. longicaudatus was used alone.

Soil amendment experiments. - A reduction in numbers of plant parasitic nematodes occurred in the amended soils. All amendments at both the 9 and 18 M.T./ha rates reduced population levels of B. longicaudatus for at least seven weeks. Phaseolus vulgaris did not appear to be a good host for either H. galeatus or C. ornatum since populations declined in all treatments. However, numbers of specimens of H. galeatus in the controls declined at a significantly slower rate than in the treatments of the cottonseed meal.

The large and rapid build-up of rhabditid and diplogasterid nematodes is an illustration of populations of nematodes increasing when their food sources increase.

The build-up of cephalobids appeared to be independent of the organic amendments presenting a reverse population trend than the other "saprophagous" nematodes.

The dorylaimid and aphelenchoid nematode populations did not increase in the amended soils. Thus no evidence was obtained to indicate that they were factors in the reduction of population

levels of the plant parasitic nematodes.

The relative numbers of fungi and bacteria were significantly higher in the amended soils than in the controls with a few exceptions. Large increases and fluctuations in numbers of zymogenous organisms, which occurred, are to be expected when a biodegradable organic material is added to the soil (1). At no time were predacious or parasitic forms observed in association with the thousands of nematodes counted. Thus no evidence was obtained to indicate that predacious or parasitic fungi or parasitic bacteria were factors in the reduction of population levels of the plant parasitic nematodes.

The carbon dioxide evolution and nitrate accumulation reflects the biodegradability and C:N ratio of the organic amendments. The highest total of 235 mg of carbon dioxide per 100 g of soil was probably far below lethal concentrations. Also, the highest nitrate accumulation of 43 ppm is far below the inhibitory level of 136 ppm reported by Eno _et al._ (12). Therefore, carbon dioxide evolution and nitrate accumulation apparently were not related to plant parasitic nematode reduction.

The inhibition of seed germination and retardation of seedling growth of _P. vulgaris_ in cottonseed meal and alfalfa meal-amended soils were similar to those noted by Patrick _et al._ (29). They attributed this reduction in plant development to phytotoxic properties formed by the decomposition of plant residues.

Extraction experiment. - Crude extracts from both alfalfa meal and cottonseed meal-amended soils reduced motility of specimens of _B. longicaudatus._ The greatest reduction in motility occurred in

the second week of incubation. The products responsible for the decrease in motility could be the same or similar to those carboxylic acids characterized by Sayre _et al._ (31) and/or those polyphenols characterized by Taylor and Murant (36) because the procedures used would have extracted both groups of compounds. The existence of these compounds in the soil could have accounted for the reduction of populations of plant parasitic nematodes observed in the amendment experiments.

None of the factors measured, e. g., fungi, nematodes, etc., could be linked to reduction in numbers of plant parasitic nematodes. Extracts from amended soils did affect _Belonolaimus longicaudatus_, and I conclude, therefore, that the products of the decomposing organic amendments were directly nematicidal and these products were, in part, responsible for reduction in numbers of plant parasitic nematodes.

APPENDIX

Explanation of Tables

Tables 1, 2, 3, and 4 contain the nematode data obtained with lower rates of alfalfa meal that were used in the initial amendment experiment.

Table 5 contains the data on numbers of aphelenchoid nematodes in the amendment experiments.

Tables 6, 7, 8, 9, and 10 contain the pH data and available nutrient data obtained in the amendment experiments.

Tables 11 and 12 contain the nematode data and relative numbers of bacteria and fungi data that were obtained at the same time the carbon dioxide data were obtained in the laboratory experiments.

Table 1. Numbers of *Belonolaimus longicaudatus* as influenced by alfalfa meal amendments in Arredondo fine sand.

Rates	Weeks											
	0	1	2	3	4	5	6	7	8	10	12	14
	Numbers per 160 g of soil											
None	7	2	0	3	4	40	99	78	92	39	44	38
2.2 M.T./ha	7	2	0	4	7	35	49	85	46	39	63	37
4.5 M.T./ha	7	2	1	2	0	8	51	61	69	31	83	56

Table 2. Numbers of *Hoplolaimus galeatus* as influenced by alfalfa meal amendments in Arredondo fine sand.

Rates	Weeks											
	0	1	2	3	4	5	6	7	8	10	12	14
	Numbers per 160 g of soil											
None	78	30	35	29	31	24	10	5	24	18	14	16
2.2 M.T./ha	78	27	45	25	20	17	14	10	23	20	37	15
4.5 M.T./ha	78	24	19	18	16	24	43	7	16	25	19	10

Table 3. Numbers of <u>Criconemoides ornatum</u> as influenced by alfalfa meal amendments in Arredondo fine sand.

Rates	Weeks											
	0	1	2	3	4	5	6	7	8	10	12	14
	Numbers per 160 g of soil											
None	350	172	297	180	180	66	88	55	99	106	63	89
2.2 M.T./ha	350	224	323	148	228	86	60	37	92	80	101	113
4.5 M.T./ha	350	128	259	129	231	46	48	33	61	63	157	78

Table 4. Numbers of other nematodes as influenced by alfalfa meal amendments in Arredondo fine sand.

Rates	Weeks											
	0	1	2	3	4	5	6	7	8	10	12	14
	Numbers per 160 g of soil											
None	59	19	48	41	180	44	78	14	48	62	103	222
2.2 M.T./ha	59	32	151	62	182	61	52	44	41	54	232	175
4.5 M.T./ha	59	30	218	106	246	97	70	31	51	27	166	228

Table 5. Numbers of aphelenchoid nematodes as influenced by organic amendments in Arredondo fine sand.

Treatment & rates	Weeks												
	0	1	2	3	4	5	6	7	8	9	10	11	12
	Numbers per 160 g of soil												
Alfalfa meal													
None	0	3	3	6	8	0	6	0	0	0	0	0	0
9 M.T./ha	0	13	12	7	4	6	0	0	0	1	1	0	0
18 M.T./ha	0	35	6	11	5	1	1	0	0	1	0	1	0
Cottonseed meal													
None	0	3	3	6	8	0	6	0	0	0	0	0	0
9 M.T./ha	0	9	19	11	12	4	4	2	0	0	0	0	2
18 M.T./ha	0	27	4	29	4	0	2	1	2	1	0	0	0
Rice Straw													
None	0	3	3	6	8	0	6	0	0	0	0	0	0
9 M.T./ha	0	8	5	6	3	0	1	1	0	0	0	0	0
18 M.T./ha	0	4	11	8	7	0	6	3	8	0	1	0	0

Table 6. Reaction of Arredondo fine sand amended with organic materials.

Treatment & rates	Weeks 0	1	2	3	4	5	6	7	8	9	10	11	12
	pH												
Alfalfa meal													
None	7.2	7.6	7.4	7.5	7.1	7.1	7.6	7.0	7.4	7.8	7.4	7.3	7.2
9 M.T./ha	7.2	7.4	7.6	7.1	7.0	7.3	7.3	7.5	7.0	7.4	7.6	7.8	7.8
18 M.T./ha	7.2	7.4	7.4	7.3	7.0	7.1	7.1	6.9	6.8	7.1	7.4	7.4	7.3
Cottonseed meal													
None	7.4	7.7	7.7	7.5	7.4	7.6	7.6	7.6	7.1	7.6	8.0	8.1	8.0
9 M.T./ha	7.4	7.4	7.7	7.4	6.9	6.8	6.6	6.3	5.7	6.0	6.8	7.1	6.3
18 M.T./ha	7.4	7.4	7.6	7.4	7.2	7.2	7.1	6.8	6.5	6.8	7.1	6.9	6.5
Rice straw													
None	7.4	7.7	7.7	7.5	7.4	7.6	7.6	7.6	7.1	7.6	8.0	8.1	8.0
9 M.T./ha	7.4	7.4	7.6	7.1	7.0	7.3	7.3	7.5	7.0	7.4	7.6	7.8	7.8
18 M.T./ha	7.4	7.4	7.4	7.3	7.0	7.1	7.1	6.9	6.8	7.1	7.4	7.4	7.3

Table 7. Ammonium acetate (pH 4.8) extractable Ca in Arredondo fine sand amended with organic materials.

Treatment & rates	Weeks												
	0	1	2	3	4	5	6	7	8	9	10	11	12
	Numbers in ppm												
Alfalfa meal													
None	452	459	490	491	452	460	461	464	459	435	435	406	406
9 M.T./ha	452	504	538	565	512	512	459	485	485	485	406	433	433
18 M.T./ha	452	629	618	618	592	592	565	645	565	538	486	565	486
Cottonseed meal													
None	450	455	459	459	459	459	406	433	433	433	433	406	406
9 M.T./ha	450	378	565	459	539	486	406	459	406	381	356	406	381
18 M.T./ha	450	476	486	486	512	486	459	459	433	486	565	459	459
Rice straw													
None	450	459	459	459	459	459	406	433	433	433	433	406	406
9 M.T./ha	450	476	486	486	459	459	433	486	459	459	459	459	459
18 M.T./ha	450	504	486	486	459	486	433	486	459	486	486	486	459

Table 8. Ammonium acetate (pH 4.8) extractable Mg in Arredondo fine sand amended with organic materials.

Treatment & rates	Weeks												
	0	1	2	3	4	5	6	7	8	9	10	11	12
	Numbers in ppm												
Alfalfa Meal													
None	18	21	25	21	23	18	28	24	25	21	16	24	26
9 M.T./ha	18	28	39	28	23	23	39	69	28	33	33	33	28
18 M.T./ha	18	63	66	39	33	44	66	69	39	44	33	50	28
Cottonseed meal													
None	18	18	5	5	14	9	33	23	18	23	28	33	28
9 M.T./ha	18	56	56	44	44	44	56	50	28	44	44	56	56
18 M.T./ha	18	91	107	76	83	91	99	99	76	91	83	91	76
Rice straw													
None	18	18	5	5	14	9	33	23	18	23	28	33	28
9 M.T./ha	18	18	18	9	9	18	28	28	28	9	33	28	33
18 M.T./ha	18	28	28	9	9	18	33	28	28	18	33	33	28

Table 9. Ammonium acetate (pH 4.8) extractable K in Arredondo fine sand amended with organic materials.

Treatment & rates	Weeks 0	1	2	3	4	5	6	7	8	9	10	11	12
	Numbers in ppm												
Alfalfa meal													
None	39	33	50	42	42	28	30	32	26	21	19	18	18
9 M.T./ha	39	113	117	124	100	78	75	42	66	58	66	38	46
18 M.T./ha	39	215	219	197	179	156	160	182	156	114	132	128	124
Cottonseed meal													
None	36	33	42	21	27	21	15	18	21	15	15	15	18
9 M.T./ha	36	102	100	107	107	90	78	81	69	58	46	42	46
18 M.T./ha	36	168	172	200	172	132	160	128	139	136	139	128	156
Rice straw													
None	36	33	42	21	27	21	15	18	21	15	15	15	18
9 M.T./ha	36	55	62	66	54	54	50	50	51	42	38	42	62
18 M.T./ha	36	92	93	84	75	85	69	69	69	81	66	66	125

Table 10. Ammonium acetate (pH.4.8) extractable P in Arredondo fine sand amended with organic materials.

Treatment & rates	Weeks												
	0	1	2	3	4	5	6	7	8	9	10	11	12
	Numbers in ppm												
Alfalfa meal													
None	55	55	47	48	47	45	43	47	43	45	48	43	55
9 M.T./ha	55	36	43	36	37	37	43	37	35	37	39	40	36
18 M.T./ha	55	40	39	42	47	40	42	41	38	42	47	60	44
Cottonseed meal													
None	50	55	43	36	35	43	36	36	35	37	37	41	40
9 M.T./ha	50	43	41	55	48	71	47	43	44	50	50	103	43
18 M.T./ha	50	50	60	71	75	70	78	68	70	74	80	73	66
Rice straw													
None	50	55	43	36	35	43	36	36	35	37	37	41	40
9 M.T./ha	50	38	37	41	34	38	37	35	36	37	43	42	41
18 M.T./ha	50	35	36	36	35	36	38	34	33	37	40	41	38

Table 11. Numbers of *Criconemoides ornatum*, *Hoplolaimus galeatus*, and rhabditid nematodes as influenced by alfalfa meal in Arredondo fine sand (laboratory study).

	Rates	Weeks				
		0	1	2	5	6
		Numbers per 100 g of soil				
Criconemoides						
	None	312	116	72	47	24
	9 M.T./ha	312	98	107	37	34
	18 M.T./ha	312	118	56	43	26
Hoplolaimus						
	None	46	16	18	11	19
	9 M.T./ha	46	21	21	4	23
	18 M.T./ha	46	20	14	0	16
Rhabditids						
	None	9	8	11	671	7
	9 M.T./ha	9	347	336	193	305
	18 M.T./ha	9	459	1,463	1,246	1,356

Table 12. Relative numbers of bacteria and relative numbers of fungi as influenced by alfalfa meal in Arredondo fine sand (laboratory study).

Bacteria	Rates	Weeks						
		0	1	2	3	4	5	6
		Relative numbers per 1 g of soil in millions						
	None	5	5	1	1	1	1	1
	9 M.T./ha	5	10	9	27	19	29	22
	18 M.T./ha	5	19	8	26	30	27	34
Fungi								
		Relative numbers per 1 g of soil in thousands						
	None	6	6	3	6	9	10	5
	9 M.T./ha	6	100	150	124	304	106	160
	18 M.T./ha	6	203	277	66	72	80	73

LITERATURE CITED

1. Alexander, M. 1964. Introduction to soil microbiology. John Wiley and Son, Inc., N. Y. 472 pp.

2. Allen, O. N. 1957. Experiments in soil bacteriology. Burgess Publishing Co. Minneapolis, Minn. 117 pp.

3. Caveness, F. E., and H. J. Jensen. 1955. Modification of the centrifugal flotation technique for the isolation and concentration of nematodes and their eggs from soil and plant tissue. Proc. Helminthol. Soc. Wash. 22:87-89.

4. Cobb, N. A. 1920. Transference of nematodes (Mononchs) from place to place for economic purposes. Science. N. S., 51 (1330):640-641.

5. Cooke, R. C. 1963. The predacious activity of nematode trapping fungi added to soil. Ann. Appl. Biol. 51:295-300.

6. Drechsler, C. 1953. Two new nematode capturing fungi. Phytopathology 53:405(Abstr.).

7. Duddington, C. L. 1955. Inter-relations between soil microflora and soil nematodes 284-301. - In Kevan (ed), Soil zoology. Academic Press Inc., N. Y. 512 pp.

8. Duddington, C. L., and C. M. G. Duthoit. 1960. Green manuring and cereal root eelworm. Plant Pathol. 9:7-9.

9. Duddington, C. L., C. O. R. Everard, and C. M. G. Duthoit. 1961. Effect of green manuring and a predacious fungus on cereal root eelworm in oats. Plant Pathol. 10(3):108-109.

10. Ellenby, C. 1945. The influence of crucifers and mustard oil on the emergence of larvae of the potato root eelworm, Heterodera rostochiensis. Ann. App. Biol. 32:67-70.

11. Ellenby, G. 1945. Control of potato root eelworm, Heterodera rostochiensis, by allyl isothiocyanate, the mustard oil of Brassica nigra. Ann. Appl. Biol. 32:237-239.

12. Eno, C. F., W. G. Blue, and J. M. Good. 1955. The effects of anhydrous ammonia on nematodes, fungi, bacteria, and nitrification in some Florida soils. Soil Sci. Soc. Amer. 19(1):55-58.

13. Esser, R. P., and E. K. Sobers. 1964. Natural enemies of nematodes. Proc. Soil and Crop. Sci. Soc. Fla. 24:326-353.

14. Jackson, M. L. 1958. Soil chemical analysis. Prentice-Hall, Inc. Englewood Cliffs, N. J. 498 pp.

15. Johnson, L. F. 1962. Effects of the addition of organic amendments to soil on root-knot of tomatoes. II. Relation of soil temperatures, moisture and pH. Phytopathology 52:410-413.

16. Johnson, L. F., A. Y. Chambers, and H. E. Reed. 1967. Reduction of root-knot of tomato with crop residue amendments in field experiments. Plant Disease Reptr. 51(3):219-222.

17. Johnson, T. M. 1959. Effect of fatty acid mixtures on the rice stylet nematode (Tylenchorhynchus martini Fielding, 1956). Nature 183:1392.

18. Lear, B. 1959. Application of castor pomace and cropping of castor beans to soil to reduce nematode populations. Plant Disease Reptr. 43(4):459-460.

19. Linford, M. F., F. Yap, and J. M. Oliveira. 1938. Reduction of soil populations of the root-knot nematode during decomposition of organic matter. Soil Sci. 45:127-140.

20. Mankau, R. 1959. Nematode trapping fungi in Southern California citrus soils. Plant Disease Reptr. 43:968-969.

21. Mankau, R. 1960. The use of nematode trapping fungi to control root-knot nematodes. Phytopathology 50:645(Abstr.).

22. Mankau, R. 1961. An attempt to control root-knot nematodes with Dactylaria thaumasia and Arthrobotrys arthrobotryoides. Plant Disease Reptr. 45:164-166.

23. Mankau, R. 1961. The effect of some organic additives upon a soil nematode population and associated natural enemies. Nematologica 7:65-73.

24. Mankau, R. 1963. Effect of organic soil amendments on nematode populations. Phytopathology 53:881-882(Abstr.).

25. Menzies, J. D. 1963. Survival of microbial plant pathogens in soil. Bot. Rev. 29:79-122.

26. Patrick, Z. A., and L. W. Koch, 1958. Inhibition of respiration, germination, and growth by substances arising during the decomposition of certain plant residues in the soil. Can. J. Botany 36:621-646.

27. Patrick, Z. A., and L. W. Koch. 1963. The adverse influence of phytotoxic substances from decomposing plant residues on resistance of tobacco to black root rot. Can. J. Botany 41:747-758.

28. Patrick, Z. A., R. M. Sayre, and H. J. Thorpe. 1965. Nematocidal substances selective for plant-parasitic nematodes in extracts of decomposing rye. Phytopathology 55:702-703.

29. Patrick, Z. A., T. A. Toussoun, and W. C. Snyder. 1963. Phytotoxic substances in arable soils associated with decomposition of plant residues. Phytopathology 53:152-161.

30. Renninger, G., J. Coffey, and B. Sokoloff. 1958. Effect of hydrogenated fish oils on citrus tree destroying nematodes. Plant Disease Reptr. 42:1057-1065.

31. Sayre, R. M. Z. A. Patrick and H. J. Thorpe. 1965. Identification of a selective nematicidal component in extracts of plant residues decomposing in soil. Nematologica 11:263-268.

32. Singh, R. S. 1964. Organic matter and biological control of plant parasitic nematodes. Uttar Pradesh, Agricultural University Magazine. 1963-64. 58-64.

33. Singh, R. S., B. Singh, and S. P. S. Beniwal. 1967. Observations on the effect of sawdust on incidence of root knot and on yield of okra and tomatoes in nematode-infested soil. Plant Disease Reptr. 51(10):861-863.

34. Steiner, G. and Helen Heinly. 1922. The possibility of control of Heterodera radicicola and other plant-injurious nemas by means of predatory nemas, especially by Mononchus papillatus Bastian. J. Wash. Acad. Sci. 12(16):367-386.

35. Stolzy, L. H., S. D. Van Gundy, and J. Letey, Jr. 1960. Oxygen tolerances of four plant-parasitic nematodes. Phytopathology 50(9):656 (Abstr.).

36. Taylor, C. E., and A. F. Murant. 1966. Nematicidal activity of aqueous extracts from raspberry canes and roots. Nematologica 12:488-494.

37. Toussoun, T. A., and Z. A. Patrick. 1963. Effect of phytotoxic substances from decomposing plant residues on root rot of bean. Phytopathology 53(3):265-270.

38. Walker, J. T., C. H. Specht, and S. Mavrodineau. 1967. Reduction of lesion nematodes in soybean meal and oil-amended soils. Plant Disease Reptr. 51(3):1021-1024.

39. Wallace, H. R. 1963. The biology of plant parasitic nematodes. Edward Arnold (Publishers) Ltd., London. 280 pp.

BIOGRAPHICAL SKETCH

Arthur Harris Tomerlin, Jr., was born November 10, 1941, at Homestead, Florida. He attended public school in Homestead, Florida, and was graduated in 1960 from South Dade High School in Homestead. He attended Dade County Junior College from 1960 to 1962, and then transferred to the University of Florida. In June, 1964, he received the Bachelor of Science in Agriculture, and in April, 1966, he received the Master of Science degree. He continued graduate study, working toward the Doctor of Philosophy.

He is a member of Alpha Zeta, Phi Sigma, Gamma Sigma Delta, Sigma Xi, Newell Entomological Society, Helminthological Society of Washington and the Society of Nematologists.

He is married to the former Mireya M. Garcia and they have a daughter, Kathrine Maria.

This dissertation was prepared under the direction of the chairman of the candidate's supervisory committee and has been approved by all members of that committee. It was submitted to the Dean of the College of Agriculture and to the Graduate Council, and was approved as partial fulfillment of the requirements for the degree of Doctor of Philosophy.

August, 1969

Dean, College of Agriculture

Dean, Graduate School

Supervisory Committee:

Grover C. Smart, Jr.
Chairman

D. A. Roberts

V. G. Perry

C. F. Eno